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BIRDS COMMON VICTIMS OF PESTICIDES

Within the span of a few weeks in 1995–96, an estimated 20 000 Swainson's Hawks were poisoned to death in farm fields in Argentina after feeding on grasshoppers sprayed with the highly toxic insecticide monocrotophos. The incident raised serious concerns about the safety of birds that use fields or forests treated with insecticides.


A robin poisoned by pesticides.

A recent analysis by Environment Canada (EC) scientists suggests that mass kills occur frequently, and that the impact of several pesticides on birds has been grossly under-estimated. This is partly because the models used currently to assess avian safety overlook important considerations and have not been formally validated by proper field studies.

Accurate estimates of pesticide-related bird kills are difficult to determine because only a tiny proportion of such kills are documented. Many poisoned birds seek cover or die away from the site where the poisoning occurred, or their carcasses decompose quickly or are eaten by scavengers. Added to this is the fact that there is generally little monitoring carried out, and that many fields and forests are not easily accessible to researchers.

EC scientists say mass kills also tend to be spread over large areas. While two or three carcasses per hectare may seem insignificant and unlikely to be noticed by the pesticide user, they spell a significant loss when extrapolated to entire areas of application. Some intensive studies carried out by the pesticide industry in the early- to mid-1980s showed how little mortality comes to light unless resources are expanded considerably in order to detect it.

Based on several such studies, scientists estimated that a single granular pesticide formulation used on corn was killing an estimated 10 to 52 million songbirds annually in the American corn belt—most of the victims members of some half a dozen species. At the peak of its popularity in western Ontario, the same product was estimated to cause 244 000 to 1.3 million songbird deaths per year. Yet, only a handful of incidents involving very few birds were reported in the United States, and not a single case of mortality was reported in Ontario.

Results of the recent analysis suggest that several products currently registered and in wide use in Canada or the US can cause significant bird mortality, even when labelled application rates and use instructions are followed. Some examples were known prior to this latest research. Diazinon, a turf pesticide commonly used on golf courses and as a home and garden insecticide, has resulted in kills of geese and other grazing waterfowl, ranging from a few individuals to several hundred. The insecticide carbofuran, used in Canada until recently, has caused endangered Burrowing Owls to abandon their colonies, and killed flocks of gulls that consumed contaminated grasshoppers.

EC scientists now believe that several other pesticides of lesser toxicity are also killing birds on a routine and largely unavoidable basis—only less frequently. The reason for this is that the impact of a pesticide depends not only on its toxicity, but also on the number of birds present—something that varies considerably among locations and different times of the year. Because birds are extremely mobile, it is difficult, if not impossible, to exclude them from treated areas. There are, therefore, very few situations in forestry or agriculture where birds are not present and potentially exposed to a spray application of a pesticide.

The mass kill in Argentina was unusual, not so much for the high toxicity of the pesticide implicated, but for the fact that a large number

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of birds happened to be present at the time of application. Despite the high number of carcasses found in such a concentrated area, it is likely that even this event would not have been noticed if researchers had not happened to be tracking individual birds from their breeding grounds in the Canadian Prairies using satellite transmitters.

The widespread use of manufactured chemical pesticides began in the 1930s as a means of controlling insect and rodent pests, fungi and unwanted plants—primarily for the production of food and fibre. They are applied in a variety of ways, including being sprayed from the air or by tractor, buried in soil, sprinkled as granules or pellets, or applied as seed coatings. Birds absorb these chemicals through their feet and skin when they are sprayed directly or come into contact with a treated surface, such as foliage. They also ingest them when preening, eat them on food or mistake them as seeds or grit, drink them in contaminated irrigation water, and inhale them as vapours or fine droplets.

Species that inhabit farmland and open areas are more likely than others to be at risk. These include waterfowl and game birds that eat large quantities of foliage, songbirds attracted to pesticide-treated seeds and insecticide granules, scavengers and predators that consume poisoned prey, and birds that feed on agricultural pests, such as grasshoppers, grubs and cutworms. The loss of the last-mentioned group of species is doubly tragic, because of the important natural role they play in controlling pest populations. Pesticides are a contributing factor to a decrease in number in the majority of farmland birds in Europe. EC scientists believe that pesticides have a similar impact on some bird populations in North America, particularly open-area species like Horned Larks and Meadowlarks.

Although pesticides are not used as intensively in Canada as they are in many other industrialized countries, they are used extensively—on cropland, as well as in commercial forests and orchards. EC scientists and international collaborators compared bird-of-prey poisoning incidents in North America and the United Kingdom, and concluded that the high proportion of poisonings that occur in Canada and the US after labelled uses of these chemicals is a reflection of how few of the more toxic pesticides have been controlled here relative to the UK.

Insecticides used on corn fields and other crops to control grasshoppers and other pests pose a threat to many bird species that feed on these insects.

Most of the problematic pesticides are cholinesterase-inhibiting insecticides—acutely toxic chemicals that kill by interfering with an enzyme vital for nerve transmission. This class of insecticide, which includes organophosphorous and carbamate insecticides, affects most vertebrates and invertebrates, and is often applied to crops more than once per growing season. Several cholinesterase-inhibiting insecticides registered today are so acutely toxic to birds that it is difficult to use them without causing mortality.

It takes only a small amount of such insecticides to kill a bird, especially a small one. Exposed birds that do not die outright may experience other physiological effects, such as impaired coordination and loss of appetite, as well as a plethora of behavioural changes. In a weakened state, they are more vulnerable to hypothermia and predation, and may be unable to attract a mate, defend their territory, or raise their broods. Many pesticides are known to cause reproductive problems in birds at rates that are not overtly toxic.

In Canada and elsewhere around the world, regulatory efforts to assess the potential impact of pesticides on birds centre on models that have never been formally validated against actual field outcomes. These models use laboratory-determined toxicity levels and estimates of food-item residues and consumption rates to make their predictions.

To see how close these models come to predicting actual impacts, Environment Canada scientists conducted an extensive review of close to 200 field studies carried out by manufacturers, government organizations and others worldwide. The field studies included surveillance of individual birds or avian populations prior to, during and after the spray application of a cholinesterase-inhibiting pesticide according to label instructions.

The results of the review, which were published earlier this year, showed that the impact of pesticides on birds is much higher than current risk-assessment models predict. This is because a number of important factors are not taken into consideration. One of the main findings of the EC study was that the dermal toxicity of a pesticide—that is, how easily it penetrates avian skin—is an extremely important factor in predicting avian mortality in the field. Dermal exposure may exceed other routes of exposure under many conditions, yet it is not currently considered in routine risk assessments. Unlike mammalian risk-assessment procedures, there is no routine testing of pesticide dermal-

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toxicity in birds, which explains why the impact of some pesticides has always been considerably higher than predicted on the basis of oral toxicity alone.

While the review showed clearly that the application rate of a pesticide affects the potential for a toxic response to occur, it also indicated the need for a means of measuring the susceptibility of birds at large to various pesticides. Too few species are generally used in dietary tests to allow a good understanding of differences in sensitivity between species.

The fact that avian mortality is common following current insect control efforts in our fields and forests may come as a surprise to many, because such cases are seldom reported. One reason is that physical searches for carcasses inside and around treated areas are difficult. Bird carcasses often blend in with their surroundings, and many are small and hard to spot. Coupled with this is the fact that scavengers remove 40 to 90 per cent of carcasses within 24 hours. Studies show that even well trained search teams sent to find "planted" carcasses on a bare field typically recover only 10 to 15 per cent. The chances that everyday users of pesticides will be aware of any problem are slim to non-existent.

Environment Canada scientists are currently using their newly developed field-study model to accurately indicate the probability of avian mortality when specific pesticides are used at given rates on specific crops. Outputs from this model have already been used to help validate product evaluation schemes designed by regulatory authorities in the European Union and in the United States, and may be considered by Canada's Pest Management Regulatory Agency in its upcoming review of organophosphorous and carbamate insecticides.

The next step in fleshing out the model will be to make it more quantitative—that is, to predict not only the probability that a given application will result in avian mortality, but also to estimate how many birds will die and the impact this may have on local populations. This is a major challenge, as it requires estimating the number of birds (including migrant species) at given sites and times of year. Canada has very few data available on the use of agricultural land by birds, and does not collect data on current pesticide use.

Open-area species such as Horned Larks are particularly susceptible to the effects of pesticides.

While they struggle to obtain these missing numbers, the scientists are carrying out a broad-brush analysis of different regions of the United States—from cotton fields in California to citrus groves in Florida—to determine areas where pesticide use may be a concern for migrating birds. In the wake of the Swainson's Hawk kills in Argentina, they are helping Argentinian agriculture officials assess the risks associated with all insecticides used in the region, and are collaborating with African scientists to evaluate insecticides used to control plagues of locusts in the Sahel region south of the Sahara Desert.

The future holds even greater challenges, with a number of new pesticides coming onto the market that are not as fast-acting as some of those currently in use. This will make it even more difficult for avian mortality to be documented accurately, as a greater number of birds will die off-site, where they can't be found. Also, because the chemical signatures for many new products have not yet been determined, it will be difficult to pinpoint the cause of death in a growing number of cases.

Although the emphasis to date has been on predicting the acute lethal effects of pesticide exposure, immediate mortality is not the only way in which bird species are being affected. Existing models say nothing about delayed mortality, reproductive effects, or the effects on chicks fed contaminated food. Also overlooked are indirect impacts on bird populations caused by the destruction of food sources and the reduction of vegetal cover in and around cropped fields as a result of pesticide use. Studies in the United Kingdom have shown a connection between available insect biomass and partridge-chick survival, and have noted a link between the availability of weed seeds and populations of other seed-eating species. Although not yet documented in Canada, it is likely that similar effects are being felt by bird species here.

It may be some time before scientists are able to say approximately how many birds die each year across Canada as a direct and indirect result of pesticide use. What is clear, however, is that the magnitude of the problem is much greater than imagined. It is only through integrated pest management—that is, by combining the use of better targeted pesticides of lower toxicity to birds with alternative methods—that farmers, foresters and other pesticide users can help reduce this impact. Such alternative methods include growing pest-tolerant species, rotating crops, planting companion crops, releasing prey, and encouraging bird and insect species that provide natural pest control through the conservation or creation of suitable habitats. S&E

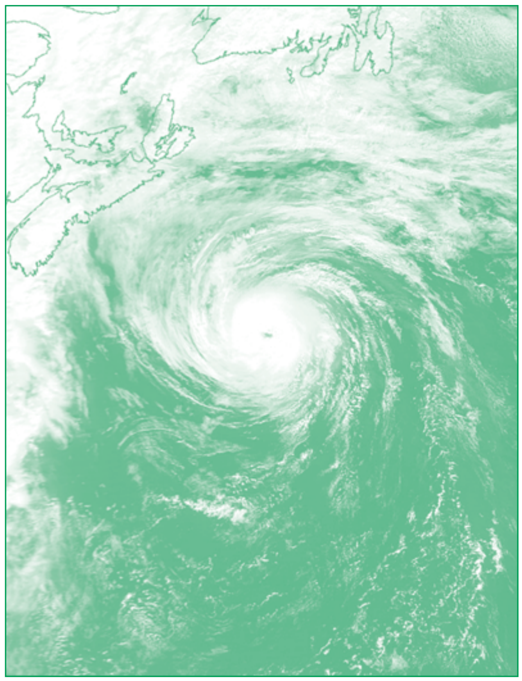
ATLANTIC HURRICANES BREAKING RECORDS

Stormy weather is on the rise in the Atlantic Basin. Over the past decade, the number of tropical cyclones—that is, hurricanes, tropical storms and tropical depressions—has increased dramatically, with 1995–2001 the most active seven-year period on record.

Meteorologists at Environment Canada's Canadian Hurricane Centre in Dartmouth, Nova Scotia, say the trend could spell trouble for coastal regions of Atlantic Canada. Although tropical cyclones often bypass these areas at sea or strike with less intensity because their energy has dissipated over the cooler waters, they frequently cause storm surges, high waves, damaging winds and heavy rainfalls. Measurable sea-level increases in recent years and the gradual sinking of the land—a geological phenomenon known as crustal subsidence—could make the risk of flooding from such storms even greater in the future.

A tropical cyclone is an almost circular storm that has a low surface pressure at the centre of its system, high winds that spiral inwards in a counter-clockwise direction, and is usually accompanied by heavy rain. Wind speed determines whether a cyclone is classified as a tropical depression, tropical storm, or a hurricane—the latter being the most intense, with maximum sustained winds of 118 km/h or higher. Hurricanes have a well-defined surface circulation and an extremely low-pressure area in their centre known as the eye. Tropical storms and hurricanes are called "named storms" because they are given proper names to make it easier for forecasters, the media and the general public to keep track of forecasts, watches and warnings in their area.

The tropical storm season in the Atlantic Basin—which covers the northeastern seaboard of Canada and the United States—usually runs from the beginning of June to the end of November, and peaks around mid-September. That's when the ocean waters that give the storms their energy are at their warmest. Generally speaking, cyclones that affect eastern North America originate in the Gulf of Mexico, the eastern Atlantic Ocean and the Caribbean Sea.



Hurricane Humberto, September 26, 2001. Photo: National Oceanic and Atmospheric Administration (NOAA).

The first tropical storm to hit the basin in 2001 arrived on June 5, and the last on December 4—making it the longest season since 1981. During this time, there were 15 tropical storms, 9 hurricanes, and 4 intense hurricanes—nearly double the previous 30-year average of 9.5, 5.6 and 2.0 respectively. The first hurricane didn't form until September 8, reinforcing the recent trend of later starts. The bulk of the activity occurred in the last three months of the season, with three hurricanes forming in November for the first time on record.

The structure of a tropical cyclone. Graphic: NOAA.

Although 2001 marked the fourth consecutive year of above-average activity in the basin, the number of named storms has been climbing steadily for more than a decade. Over the past century, the average was 8.7 per year, while over the past 50 years it was 9.9. From 1991 to 2000, the number jumped to 11.8—the highest 10-year average on record—with 6.9 hurricanes and 2.8 intense hurricanes per year on average.

In Atlantic Canada's "response zone"—the coastal region north of Virginia to the island of Newfoundland—the average annual frequency of named storms has been 3.3 over the past 100 years, 4.2 over the past 50 years, 4.4 over the past

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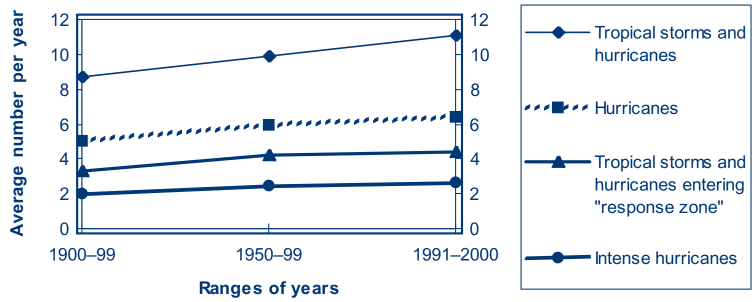
decade, and 5.7 over the past seven years. Over the last three years, the zone has seen six named storms per year, many of which have caused flooding in parts of Newfoundland, Prince Edward Island, New Brunswick and Nova Scotia.

In 1999, remnants of Harvey converged with another active storm and dumped 302 mm of rain in a 30-hour period in Oxford, Nova Scotia. In October 2000, Michael made landfall in Newfoundland with peak wind gusts of 172 km/h, and a significant storm with tropical moisture passed east of Cape Breton, Nova Scotia, causing a 1.5-metre storm surge and 12-metre-high waves that flooded northern Prince Edward Island and southern New Brunswick. During a particularly busy 30-day stretch from late August to late September 2001, four tropical storms moved through the waters of the southwestern Grand Banks, each delivering rainfalls in excess of 100 mm on Newfoundland. Gabrielle set a six-hour rainfall record of 90 mm in St. John's, prompting the mayor to call it "the worst storm in 100 years."

There is no doubt that the Atlantic Basin is experiencing a period of increased tropical storm frequency. As with many storms, hurricane activity occurs in cycles that last anywhere from a year to a century. For example, hurricanes were quite active in the basin from the 1930s to 1960s, but were relatively quiet in the 1970s and 1980s.

Average sea-surface temperatures and salinity have been above normal since the 1980s—a situation that primes the ocean for the creation of tropical cyclones. Other climatic conditions have also influenced the formation of hurricanes over the past several seasons, including enhanced monsoons in West Africa, a favourable configuration of the westerly jet stream over Africa, and reduced vertical wind shear (or the change in wind speed and direction with height) over the heart of the hurricane development region.

Average number of tropical cyclones in the Atlantic Basin for 1990–99, 1950–99, 1991–2000



Although global predictors are sending a mixed signal for the Atlantic Basin this season, hurricane activity is expected to be near normal. Experts say that while tropical Atlantic sea-surface temperatures are neutral in terms of storm development, stratospheric winds are supportive, and the weak-to-moderate El Niño that has been forecast for this fall could act as a suppressant.

Scientists in Canada and the United States are closely monitoring the many factors that influence the creation of tropical cyclones in an effort to improve the forecasting of these events and the lead time they are able to provide to the public. They are also studying the trends that sea-surface temperatures, wind shear and other factors are undergoing, to determine whether they are being influenced by climate change.

Whatever the underlying causes behind the increase in storm activity in the Atlantic Basin, the message to planners, emergency-response organizations and others in the region is evident: steps must be taken now to prepare for what could be a significant risk of flooding in coming years. S&E

A RECIPE FOR TROUBLE

Several key ingredients are needed for a tropical cyclone to form. The first is sea water with a surface temperature of at least 26.5°C. The warmth from the water and the latent heat created through condensation give the storm its energy.

Tropical storms also require an atmosphere that is potentially unstable. If the atmosphere cools generally with height, and has a high-pressure area with an outward flow in its upper regions, air will be encouraged to rise up from the lower levels.

This disturbance will grow only if winds at all levels of the atmosphere—from ocean level to over 9 kilometres—are blowing relatively lightly, at the same speed and from the same direction. In other words, the vertical wind shear must be low in order to allow the rising air to flow upwards without disruption. El Niños cause high wind shear, and therefore have a dampening effect on the creation of tropical cyclones.

Finally, tropical cyclones cannot form closer than about 500 kilometres to the equator, or the Coriolis effect caused by the rotation of the earth will be too weak to promote circulation.

MONITORING WATER QUALITY FROM SPACE

Since *Landsat-1* was launched 30 years ago, remote monitoring has provided scientists with a plethora of information about earth's physical and biophysical features. Yet, while satellite data have taught us a great deal about our planet's terrestrial and mid-ocean regions, they have told us little about our inland and coastal waters until now.

The quality of inland and coastal waters is vital to human and environmental health, as well as to the strength of Canada's resource-based economy. The use of satellites to monitor water quality would be a great asset in protecting and sustaining this resource, because it would provide scientists and decision makers with an early warning of environmental stresses or increased vulnerability in a particular region.

Satellite monitoring of inland and coastal waters is much more complex than monitoring mid-ocean water quality. That's because water colour—which is an indicator of water quality—is caused by the absorption and scattering of sunlight and skylight by organic and inorganic matter in the water.

In mid-ocean water, the only colourant is chlorophyll-bearing phytoplankton and its decay products. Therefore, it is a relatively straightforward process for scientists to use remote-sensing models and algorithms to deduce concentrations of ocean chlorophyll based on the optical properties of this single colourant.

With inland waters, the colour of natural water adjacent to or surrounded by a land mass is determined not only by phytoplankton and decay products, but also by other coloured substances. These include suspended sediments and dissolved organic matter that come from the land. Very often, these colourants can mask the contribution of chlorophyll to the water colour as recorded at satellite altitude.

Researchers at Environment Canada's National Water Research Institute (NWRI) have overcome this dilemma by developing a model that simulates the transfer of energy and the spread of radiation from the sun and sky through and below the point at which the air and water interface. From this foundation, they have created a bio-optical model and analytical techniques that allow them to determine concentrations of chlorophyll, suspended sediments and dissolved organic matter from one remote measurement of water colour.

Scientists liken the process to mixing paint. By knowing the individual colours of the different components of the water—for example, green chlorophyll, red clay, and tea-coloured dissolved organic matter—the model is able to calculate how much of each must be present to produce the colour measured by the satellite.

With this technology, researchers can now evaluate inland water quality from space. NWRI scientists successfully applied the model to Lake Ontario waters and it later formed the basis for water-quality studies of Lake Ladoga, Russia, within NWRI's long-standing contribution to the Canada–Russia Bilateral Environmental Cooperation agreement. This past year it has been applied to the remote sensing of Lake Erie water quality as part of the Canadian Space Agency's Earth Observation and Applications Development Program.

Now researchers plan to use historical and current satellite information, along with data from new environmental satellites equipped with sophisticated spatial and spectral resolution, to detect and monitor environmental trends in lakes and rivers across Canada. They can then create "water quality mosaics" of sites to assess the impacts of environmental stresses on Canadian water resources.

Although monitoring water quality by remote sensing will never replace ground-based monitoring, this method has many potential applications that could help protect the environment and benefit the economy. For example, following up on early indicators of ecosystem damage by taking prompt corrective action could increase the sustainability of forestry, agriculture, and resource development. Such information will also enable researchers to evaluate how well a restoration program is improving water quality—a definite advantage at a time when Canadians are increasingly concerned about the quality of their water.

A view of Lake Erie by satellite. Different shading indicates differences in water quality in various parts of the lake.

Environment Canada is now working with the Canadian Space Agency on a Space Strategy for the Government of Canada. The strategy is intended to ensure that the vast amount of environmental data gathered by satellites in the coming decade will be used to maximum benefit in confronting issues such as climate change, biodiversity, air quality, and water quantity and quality. S&E

REDUCING MARINE VESSEL EMISSIONS

Although international shipping produces only about seven per cent of the world's nitrogen oxide (NO_x) emissions, the impact of these pollutants on local air quality can be significant. Each year, for example, Vancouver has to contend with NO_x emissions created by 8000 marine-vessel movements in its harbour.

Produced primarily by the burning of fossil fuels, NO_x and volatile organic compounds (VOCs) react in sunlight and stagnant air to form ground-level ozone—one of the primary components of smog. This form of ozone can harm human health and also causes damage to plants and synthetic materials.

But NO_x and VOCs aren't the only air pollutants released from the smokestacks of ocean-going vessels. Particulate matter (PM), sulphur dioxide, carbon dioxide and carbon monoxide also make up part of the blend. PM is the other major component of smog, and consists of microscopic inhalable material that can cause respiratory and cardiac problems.

In an effort to reduce airborne pollution from ships, the International Maritime Organization (IMO) has negotiated NO_x standards for marine vessels and is seeking similar controls for particulate matter. The NO_x standards are currently pending acceptance by all members of the IMO, including Canada.

Environment Canada's Environmental Technology Centre has been working with Transport Canada for over a decade to determine the emissions from marine vessels in Canada and to investigate potential emission-control technologies for diesel engines that are currently in use. Studies carried out on a small fleet of cargo, container, and cruise ships in the Vancouver area and on the MV *Cabot*—a cargo vessel operating between Montréal and St. John's—have indicated that NO_x emissions from such vessels exceed IMO standards in many instances.

Two promising aftermarket technologies for reducing NO_x and other emissions from diesel engines use water to cool the engine's combustion chamber. Both water-injection systems, which introduce small quantities of water into the engine's air intake, and fuels made of water–diesel emulsions reduce the engine temperature by using some of its heat to vaporize water. The lower temperature results in lower emissions of NO_x and PM. Engines that run on water–diesel emulsions produce even less pollution than those with water-injection systems, because they burn less fossil fuel.

Tests conducted on a manual water-injection system installed on the *Queen of New Westminster,* a passenger/car ferry operating in British Columbia, showed the potential for NO_x reductions of 15–25 per cent. Since then, the Environment Canada–Transport Canada project team has developed a computer-controlled version of this system that boosts these reductions to 20–28 per cent, according to laboratory results. Transport Canada is currently creating a tailored version of the system for use and testing on board the MV *Cabot*.

To measure differences in emission and performance levels, Environment Canada evaluated water–diesel fuel emulsions containing 5, 10, 15 and 20 per cent water by weight. The 20 per cent blend resulted in the largest exhaust emissions reductions, cutting NO_x by 8 per cent and PM by 83 per cent. A commercial version of this blend is already being marketed by a private company.

In an effort to boost NO_x reductions, further tests were carried out on the effects of changes to the fuel-injection timing. Retarding the timing in a regular diesel engine lowered emissions of NO_x and hydrocarbons, but boosted emissions of carbon monoxide, carbon dioxide and particulate matter. Increasing the timing had the opposite effect. By using a 20 per cent water–fuel emulsion and retarding the timing slightly, reductions of 58 per cent NO_x and 72 per cent PM were achieved.

One of the downsides to fuel emulsions is that fuel efficiency and power decrease as the percentage of water in the emulsion increases, because less energy is available from the combustion process. Water-injection systems have a similar but less pronounced effect. Also, introducing too much water into an engine can stifle the combustion process and increase the formation of hydrocarbons, carbon monoxide and PM.

Environment Canada has a patent pending on a new method of blending water and fuel mechanically, just before they enter the combustion chamber. The new system allows the user to vary the water-to-fuel ratio to suit the vessel's current power needs—an important factor during storms and other emergencies.

Through their efforts to test and develop technologies that reduce the harmful emissions created by in-use marine engines, researchers will help to improve air quality in busy port cities on both coasts of Canada and around the world. S&E

PLAYING FOR KEEPS

While most people have some idea of the kind of world they would like to create for the future, few of us know how to make it a reality. Yet, every day, we make dozens of choices that will inevitably affect our lives and the environment in years to come—from the products we buy to the way we get to work in the morning.

To help people understand the impacts of these choices, researchers at the University of British Columbia (UBC) have teamed up with Environment Canada and other government and private-sector partners to develop an interactive computer game that enables players to design their own destinies.

QUEST was originally created for the basin of the Fraser River, which runs from the interior of British Columbia into the Strait of Georgia, near Vancouver. Over the past four years, however, it has been tailored to include geographic, environmental, social and economic data pertaining specifically to the province's Georgia Basin. This region—which includes the southwestern mainland of B.C. and the southeastern edge of Vancouver Island—is expected to experience serious environmental stresses due to rapid population growth over the next 10–25 years.

QUEST was developed to engage members of the local community and others in finding solutions to some of the difficult challenges the basin will face in the areas of transportation, urban growth, land use, fisheries, forestry, waste management, housing, air pollution and wildlife habitat.

By modelling the complex way in which social, ecological and economic factors in the region interact, QUEST enables people to explore how the choices they make today will affect their lives and the environment 40 years from now. Environment Canada has supported the game's development by sharing the Department's geographic and scientific data and modelling expertise, assisting with public outreach activities, and providing funding through the Georgia Basin Ecosystem Initiative.

Although it can take as little as half an hour to play QUEST, players can and do spend hours exploring different options. In addition to being asked to select the kind of political future they envision for Canada, players identify the issues that are most important to them and make a number of lifestyle choices. QUEST also outlines various policies that might be put into place to enforce laws and regulations—thereby enabling players to ascertain the type of leadership they want.

QUEST helps players see the human footprint on British Columbia's populous Georgia Basin region.

After their choices have been made, players see indicators and stories explaining the major issues and trends of the day 40 years from now, as well as graphs indicating how the economy, environment and other aspects of life have changed over time as a result of their decisions. QUEST also allows players to go back and alter their choices, to see how their outcomes would change as a result.

Hundreds of users have provided feedback on a trial version of QUEST that went on line in fall 2001 at [www.basinfutures.net]. A final version of Web-QUEST is being worked on, and a standalone version, "Workshop QUEST," will be completed in September 2002. A simplified video version designed specially for children also runs regularly in the Decision Theatre at Vancouver's Science World—where full versions of the game can be used for public meetings, focus groups, and workshops involving land managers, town councillors, city planners and others.

The choices made by QUEST players are saved (with their permission) and will be studied by the Sustainable Development Research Institute team at UBC to determine the types of futures people envision for the basin, and the trade-offs they are prepared to make to attain them. This information will be helpful to policy and decision makers in industry and government, and should lead to better, more informed and more sustainable ecosystem-based choices.

In addition to refining and improving the current trial version of QUEST, UBC is looking to expand the model to include Washington's Puget Sound area, as the Georgia Basin ecosystem extends south of the Canada/United States border. In the meantime, the original developers of the QUEST model have finished preliminary versions for Mexico City, Canterbury (New Zealand), northwestern England, and Bali. S&E

S&E Bulletin

This bi-monthly newsletter provides information on Environment Canada's leading-edge science and technology.

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